Chapter 24

NEW PUBLIC TRANSPORTATION TECHNOLOGY

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The subjects of this chapter are urban public transportation systems that represent significant changes and advances in equipment, facilities, operations, and services, in comparison with conventional rail, bus, taxi, and other street modes. System-level advances, such as automated and remote controls, are the focus of attention, rather than improvements in subsystems or components, such as engines or brakes for existing modes.

The names of advanced systems have not yet been standardized; however, the system classes of main interest are discussed under the following headings:

- Automated guideway transit (AGT).1 Shuttle-loop transit (SLT). Group rapid transit (GRT). Personal rapid transit (PRT).
- Rent-by-the-trip public automobile service (PAS).
- Dual-controlled AGT (D-AGT).
- Automated mixed-traffic vehicles (AMTV).
- Accelerating moving ways (AMW).
- Fast transit links (FTL).

The term *advanced systems is* used to refer to all such systems.

Four themes are presented. First, an entirely new standard of urban public transportation service is needed, and deserves public financial support, to ensure that transportation-disadvantaged individuals have equal access to opportunities and to provide nonautomobile alternatives for others. This new standard is *called full-service transit* and refers to service of good quality for all urban residents, at all times of day or night and for all trips throughout urban areas. Second, it is technically feasible to develop advanced transit systems that have a variety of valuable new characteristics. Third, a combination of systems, deployed in complementary sets throughout urban areas, can greatly improve the quality, increase the quantity, decrease the unit costs, and ease the accessibility of urban public transportation service. Fourth, the benefits and costs of each proposed system should be assessed in terms of its potential contribution to full-service transit and in comparisons with alternative systems.

EVOLUTION OF INTEREST

Work on advanced systems of some types, such as an accelerating moving way, was done as early as the late nineteenth century. However, the development and use of advanced systems did not attract significant interest and effort until the mid-1960s. Progress has occurred mainly since the passage of the Reuss-Tydings Amendments to the Urban Mass Transportation Act of 1964. The act required the Secretary of Housing and Urban Development to

> undertake a project to study and prepare a program of research, development, and demonstration of new systems of urban transportation that will carry people and goods within metropolitan areas speedily, safely, without polluting the air, and in a manner that will contribute to sound city planning. The program shall (1) concern itself with all aspects of new systems of urban transportation for metropolitan areas of various sizes, including technological, financial, economic, governmental, and social aspects; (2) take into account the most advanced available technologies and materials; and (3) provide national leadership to efforts of States, localities, private industry, universities, and foundations.2

The summary report of that project was submitted by President Johnson to the Congress in May 1968.3 That report and numerous input documents prepared by contractors stimulated interest in the planning of advanced systems in the United States and abroad and provided much of the basis for planning research and development programs by the Urban Mass Transportation Administration (UMTA) from 1968 through the early 1970s. One of the input documents4 described several conceptual systems of the kinds discussed in this chapter.

Immediate and strong interest was shown by inventors, private sector research and development institutions, transportation planning consultants, government transportation agencies at all levels, industrial firms seeking roles as suppliers, and prospective owners and operators of advanced systems. AGT systems were the main focus of attention, but smaller efforts were applied to several other advanced systems. Industrial firms and government agencies in the United States, Canada, Western Europe, and Japan had spent more than $200 million by the mid-1970s on research, development, prototype fabrication, and testing of advanced systems and on the installation of AGT systems in four U.S. airports, a few recreation parks, a university, a hospital, and two multipurpose real estate development. During this period. UMTA initiated a program called the Downtown People Mover Project to exploit fully developed, market-ready AGT systems in numerous central business districts. The scope of that program was greatly reduced and, in 1990, included only systems located in Miami and Jacksonville, Florida, and Detroit, Michigan. After the mid-1970s UMTA's appropriations were reduced and their programs to develop AGT systems, dual-mode buses, high-speed transit, and other advanced systems were eventually abandoned. By 1980 the hope that UMTA would provide leadership in the development of advanced systems had ended.

Throughout the 1970s and 1980s, recreation parks and airports were the most important markets for AGT systems in the United States. Many capable United States firms concluded that opportunities for supplying advanced urban public transportation system for profit were lacking and withdrew from the business. Yet several firms did remain active and supplier interest increased in the 1980s. By 1990, systems had been installed for urban public transportation service in Canada, Australia, England, Japan, France, Germany, and the United States, and AGT projects in progress for urban and other settings had a total estimated capital cost of more than $9 billion.5

WHY INNOVATE?

Interest in exploiting advanced systems can usually be related to these arguments:

- Important needs of society can be satisfied only by increasing travel via urban public transportation modes.
- Conventional taxi, bus, and rail systems; private autos; bicycles; and so on, cannot provide the quantity and quality of service needed because of inherent physical, cost, and operating characteristics.
- Sets of advanced systems in combinations promise a variety of capabilities needed to provide full-service transit to all travelers, for all trips, at all times, and throughout entire cities and metropolitan areas.

NEEDS OF SOCIETY

The case for improving and expanding urban public transportation service to benefit society is based on two premises. First, there is a need to provide more and better transportation service to certain transportation-disadvantaged individuals who have limited mobility via automobile and transit. Among these are the young, the old, the poor, the handicapped, individuals who lack driving skills, unlicensed drivers, persons who do not have first claim to an auto, and those who do not have access to transit. The transportation disadvantaged need improved mobility to gain equal access to opportunities of all kinds—employment, residences, schools, recreation, cultural resources, professional services, retail stores, and intercity passenger terminals. The proportions of the population who are transportation disadvantaged vary greatly among cities and neighborhoods and also with individual circumstances; but, overall, the transportation disadvantaged may be on the order of 40% of the urban population.

Second, there is a need to shift a great fraction of existing urban travel from the private automobile to public modes to achieve a variety of objectives. Foremost among these are reducing air pollution, saving energy (especially petroleum fuel), controlling urban development patterns, conserving land, reducing the time and effort of travel, and reducing accidents.

Voters frequently indicate support for transit service by approving increased taxes and other uses of public funds to subsidize conventional urban public transportation services even though these systems may provide service of poor quality. If only conventional modes were used to provide full-service transit, the burdens of subsidies would be severe. Subsidies needed for advanced systems may be acceptable, however, if the average cost of subsidies per trip can be greatly reduced or eliminated. This may be achieved through intensive efforts to achieve cost-effective systems and by the economies of scale resulting from increased travel by the transportation disadvantaged plus the diversion of some riders from automobiles. Transit patronage, now roughly 3% of total urban travel, may be increased as much as tenfold.

LIMITATIONS OF CONVENTIONAL TRANSIT MODES

Existing transit modes are limited in hours of operations, frequency of service, and accessibility, especially in areas where demand density is low. Foremost among the limiting factors are high capital costs, high labor costs, and the aesthetic offense of elevated guideways and stations. Other limiting factors are inflexible operations, low utilization of capacity, and inefficient use of energy. Existing modes can be improved, but these disadvantages cannot be eliminated entirely.

Concerns regarding the visual impacts and noise of elevated rail transit systems cause strong opposition by property owners and residents along the routes. Consequently, many elevated rail systems built in the early 1900s have been demolished and replaced with bus service. To avoid such objections, new rail systems have placed parts of their routes underground at costs and with delays so great that completion of the entire project was often endangered.

The capital cost of heavy rail systems is on the order of \$100 million/mi (in 1990 dollars) when a mix of underground, at-grade, and elevated guideways is used, as in the Washington, D.C., Metrorail. Such costs limit applications of heavy rail to a few large cities and, within those cities, to a small fraction of the routes that need transit service. Light rail systems can be less costly. For example, the estimated total capital cost of a proposed elevated light rail system in Orange County, California, was about \$36 million/mi, at 1982 prices. The cost of constructing guideways, stations, and related structures was estimated to be $24 million/mi, about two-thirds of the total capital cost. The capital costs of light rail systems at grade in street rights-of-way are less than on elevated structures, but much higher than those of the bus systems with which they must compete. Consequently, light rail systems also have limited application.

Most AGT systems in existence use elevated structures, and conceptual designs for urban applications of advanced systems usually assume that elevated structures will be used. The design of advanced systems will reduce, but will not eliminate, the problems of aesthetic offenses and burdensome capital costs of elevated rail structure. Therefore, the extent of the application of advanced systems will depend, in large part, on the ability of designers to minimize aesthetic impacts and to achieve low construction costs. These difficulties suggest that advanced systems capable of operating on nonexclusive guideways at street level also warrant serious attention.

The high cost of labor is a limiting factor in all conventional systems. Labor is, by far, the dominant element in the cost of providing taxi service, so taxi operators tend to concentrate service at times of day and in areas where demand for service is high. From the viewpoint of the taxi operator, this practice minimizes cruising, empty returns, and waiting time. It also provides slow and unresponsive service, or no service, in low-density areas and at times of low demand, although modern dispatching and control systems have alleviated part of this problem in some cities.

Labor also accounts for a major part of bus operating costs, for example, about 80% in a typical large bus system. It is not possible to schedule work shifts and vehicle operations in ways that fully utilize labor. The productivity of bus drivers, in numbers of passengers served per hour of work, is low because of time spent waiting and moving empty buses, and because buses in revenue service cannot utilize their full passenger capacity during periods of slack demand and when traveling in the off-peak direction. Rail systems are also unable to fully utilize labor, but the cost of direct labor per unit of capacity is relatively low, and direct labor costs are less important than in bus systems.

Private automobiles dominate urban travel because of these major advantages: self-service operation makes automobile service available at no direct labor cost; perceived capital costs are low; the capital costs of roads are quite low, on the order of 1 cent/vehicle-mi; and automobiles provide door-to-door, personal service superior to transit modes for most urban trips. Automobiles also have serious limitations. Service is not available to many because of prohibitive costs and the inability to acquire driving skills and a license. Enormous commitments of land and capital are made for traffic lanes in streets and roads, curb-side parking, driveways and garages at residences, parking at businesses and public buildings, and public parking lots and garages. These facilities must be supplied in relative abundance to provide access to all addresses and to avoid congestion, excessive travel times, and high operating costs. Although some streets are heavily traveled, most city streets have unused capacity that could accommodate advanced street modes. Dependence on the automobile encourages the exploitation of low-cost land and the development of low-density, sprawling communities. Automobiles are major contributors to air pollution, although emissions have been reduced by changes in automobile design and maintenance requirements, and further improvements can be made. The depletion of nonrenewable petroleum resources and dependence on foreign petroleum also influence automobile design and in the future will cause shifts to other energy types and sources, as well as major reduction in vehicle size, weight, performance, and operation. Fatalities, injuries, and property damage from automobiles are tolerated by the public and may not limit travel; however, improved safety is highly desirable. Substituting transit for automobiles in cities will help to overcome these problems.

PROSPECTIVE ADVANTAGES OF ADVANCED SYSTEMS

Each of the advanced systems discussed here promises one or more important advantages over conventional modes; however, no single system combines all the desired features. Therefore, sets of complementary systems will be required to provide full-transit service for entire cities. The main avenues for improvement are:

1. Automatic controls, remote controls, self-service controls, and continuous or process-type operations promise low labor costs and, consequently, a capability to provide service on low-demand routes not presently served and frequent scheduled service or service on demand at all times, 24 h/day and every day. Automation and remote control also promise low labor cost for vehicle movements in stations, yards, and shops.
2. Small vehicles, structures, and stations of some AGT systems promise relatively low capital costs per lane-mile. Aesthetically pleasing vehicles, guideways, and stations also promise to reduce opposition to elevated structures.
3. Advanced street systems such as AMTV and PAS promise very low capital costs per lane-mile by avoiding the construction of guideways and stations. Low costs will permit the installation of advanced systems in fine-mesh networks and in areas of relatively low population density and transit demand. The appearance of advanced street vehicles on nonexclusive guideways at grade will be much less offensive than elevated structures and will more likely be accepted.
4. Fine-mesh networks promise short walking distances and easy access to transit service.
5. Advanced street modes promise easy access and acceptable speeds for short trips.
6. Advanced systems promise direct routes, short delays to board vehicles, off-line stations to avoid stops at en route stations, coupled links at the nodes to eliminate transfers, short travel times, and reduced travel effort.
7. Mechanized stations and platforms at grade promise easy access to vehicles and savings of time, effort, and inconvenience of travel

8. Electric propulsion promises savings of petroleum fuel, low noise, and low air pollution by vehicles.
9. Accelerating moving ways (AMW) promise attractive speed for very short trips and large capacities without using large amounts of space to accommodate vehicles.
10. Fast transit link (FTL) systems promise acceptable travel times for very long trips of up to 100 miles.

This chapter focuses on the characteristics that aid in defining the capabilities and roles of actual and conceptual systems in a full-service transit program. Space does not permit full descriptions. Detailed factual data and illustrations will be found in the *International Transit Compendium*,[6] assessment reports sponsored by UMTA and usually obtainable from the U.S. Department of Commerce National Technical Information Service, proceedings of professional society conferences,[7,8] the *Transit Pulse* newsletter,[9] and trade literature. Life-cycle cost estimates for several systems will be found in *Cost Experience of Automated Guideway Systems.*[10] Estimates of life-cycle direct and indirect energy demands for several systems will be found in *Energy Study for Automated Guideway Transit Systems.*[11]

AUTOMATED GUIDEWAY TRANSIT (AGT)

Automated guideway transit (AGT) systems are characterized by the use of exclusive guideways and vehicles operated without a driver on board. In a full-service transit program, AGT networks would extend throughout urban areas and provide a large fraction of all needed services.

AGT systems are attractive for several reasons. They have low direct labor costs for the operation of vehicles in revenue service and for vehicle movements in yards and shops. Exclusive guideways eliminate interference from pedestrians and vehicles of other types and permit vehicles to travel at average speeds higher than those usually attained by vehicles in mixed traffic. AGT systems have demonstrated excellent safety and reliability and can be safer and more reliable than driver-controlled buses, automobiles, and taxis. They use electric propulsion, conserve petroleum fuels, and are quiet and nonpolluting.

In the 1970s and 1980s more than a dozen companies developed and placed in service some 50 AGT systems. Systems of many kinds not yet developed could be conceived. Discussion of AGT systems is aided by using names for three subclasses: *shuttle-loop transit* (SLT), *group rapid transit* (GRT), *and personal rapid transit* (PRT). The main attributes of each class are summarized in Table 24-1.

Technical and scientific knowledge at hand or attainable gives designers of AGT systems freedom to tailor system performance and capacities to match expected loads

TABLE 24-1
CHARACTERISTICS OF AGT SYSTEMS

Category	SLT	GRT	PRT
Vehicles	Any desired capacity. Single units or trains Length	Intermediate capacity (e.g., 12-40 passengers) single units or short trains	Small capacity(e.g, 1-6 passengers single units (in most concepts).
System Configurations	Lines are independent shuttle and loops. Stations are on-line Switches are usually	Lines branch and merge . Stations are usually off-line. Switches are required	Line cross, branch, and merge at interchanges. stations are usually off-line. Switches are Required.
Areawide Networks	Use many interfacing shuttles and loops	Use multiple interfacing intersecting GRT systems	Use a single interconne-cted coupled network
Standardization	The design, capacity Performance, and Supplier of each SLT element of a Network may differ From all others	The design, capacity, performance, and supplier of each GRT element fo a network may differ from all others	A single design must be used for the entire net-work, although capacity and performance may differ among links
Operations	Vehicles follow single Routes. No switching or rep-Etitive switching Pattern.	Vehicles follow multiple Routes. repetitive switching under normal loads; may be Demand responsive in Slack periods. Switching is responsive To the identity of each Vehicle.	Unlimited route variat-Ions. nonrepetitive switch-ing. Demand reposi-ve to requirements To requirements of each vehicle.
Passengers	Board first available vehicle. Stop at all intermediate stations. Share vehicles. Make numerous transfers in networks.	Wait to board the parti-Cular vehicle that will stop at the desired loc-Ation. Share vehicle. Make some transfers in networks.	Board first available vehicle. No stops at intermediate stations. Individuals or small travel parties have private use of vehicle Make transfers.

and a broad range of performance and operational requirements. AGT systems can have lower capacities, lower performance, and lower capital costs per lane-mile than rail transit, although capital costs per lane-mile would be higher than buses. AGT systems can have operating costs lower than rail transit and much lower than bus transit or taxis. The indirect labor costs of maintenance and of monitoring automated operations vary greatly among existing AGT systems and, for many systems, are high enough to limit applications.

SHUTTLE LOOP TRANSIT (SLT)

SLT systems are the simplest, best understood, and most widely used of the three classes of AGT systems. Shuttle vehicles are bidirectional and operate between pairs of terminals. Loop vehicles travel around closed loops and may be either unidirectional or bidirectional. All such AGT systems are called shuttle-loop transit (SLT). They are also called *automated people movers* (APM), *people movers* (PM), *downtown people movers* (DPM), and intermediate-capacity rapid transit (ICRT). For a discussion of intermediate-capacity systems using standard-gauge railway track guideways, see Chap. 5. Diagrams representing alternative shuttle and loop layouts appear in Figs. 24-1 and 24-2.

Designers of SLT systems can choose characteristics to provide a great range of capacities, speeds, and frequencies of service. The *theoretical capacity* of a transit lane is based on the assumption that each vehicle is fully loaded for every trip. The capacity actually attainable in practice is significantly lower. *Route capacity* in passengers per hour per direction (p/h/d) varies with the passenger loads of individual vehicles, the number of vehicles in trains, the number of round trips per hour, and the number of parallel paths on a route. The number of round trips per hour varies with the length of the shuttle line, the average travel speed, and the average dwell time at the stations. Vehicle cruise speed is also subject to wide variation. *Average speed is* lower than cruise speed, depending on acceleration and deceleration rates, reduction of speeds at curves, and distances between stations. Frequency of service and lane capacity vary with the length of shuttles.

A single shuttle guideway [see diagram (a) of Fig. 24-1] carries one vehicle or train traveling back and forth between two terminals. It provides service to the terminal stations and to intermediate stations if desired. Addition of a bypass [diagram (b)] allows two vehicles or trains to operate simultaneously, thereby increasing capacity 100% and reducing waiting time 50%. The use of dual-shuttle guideways [diagram (c)] has the same result. A dual shuttle with switches at the terminals [diagram (d)] allows vehicles to change guideways for return trips (also called *a pinched loop).*

A single loop with parallel guideways [diagram (e)] provides two-way service among two or more stations. A single loop with an open guideway pattern [diagram (f)] can provide one-way service through an area and is often used in recreation parks. Open loops require those travelers making round trips to follow circuitous paths and usually require extra travel time. Dual loops with parallel guideways [diagram (g)] provide two-way service, can have greater capacity, avoid the need for circuitous travel,

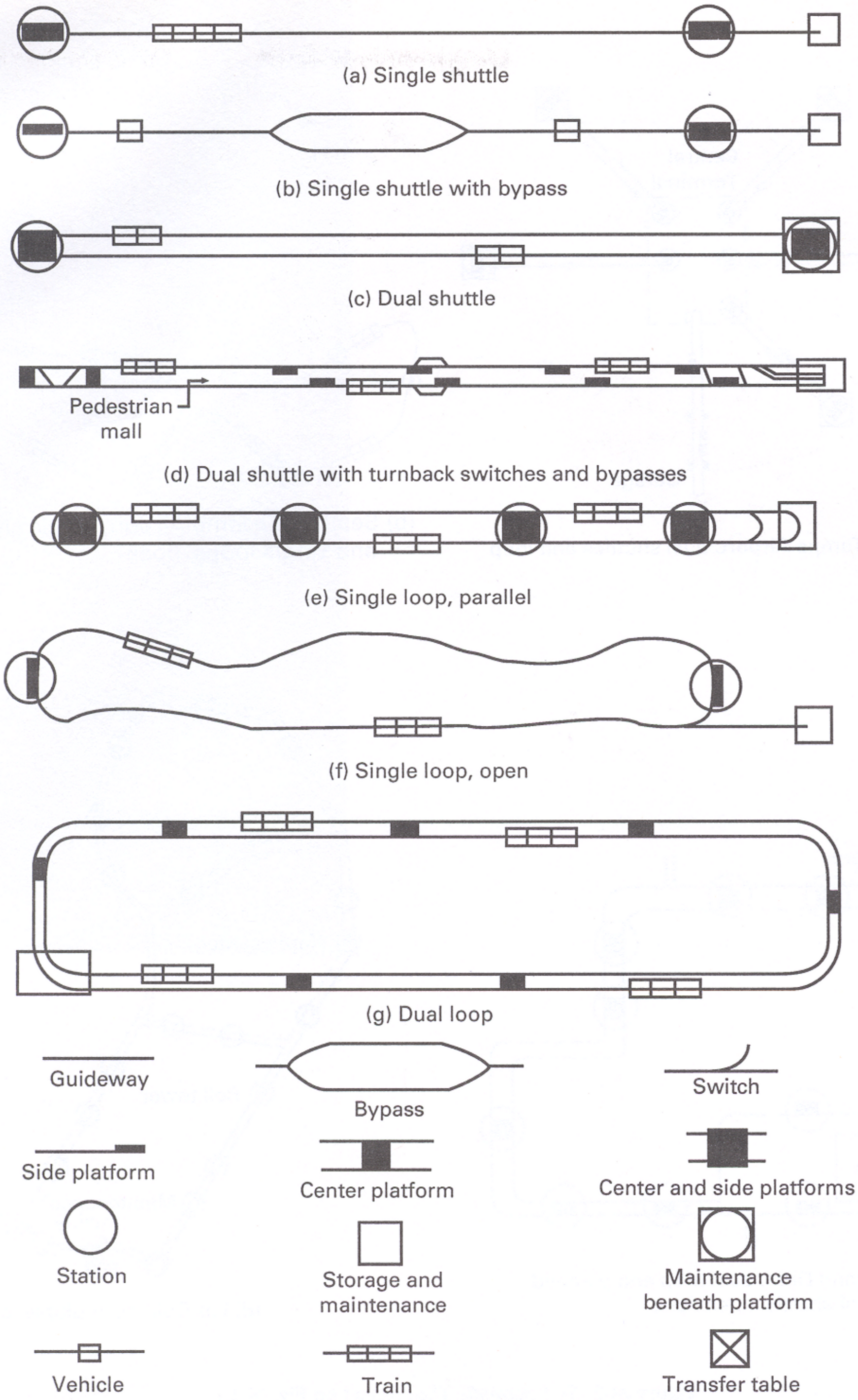
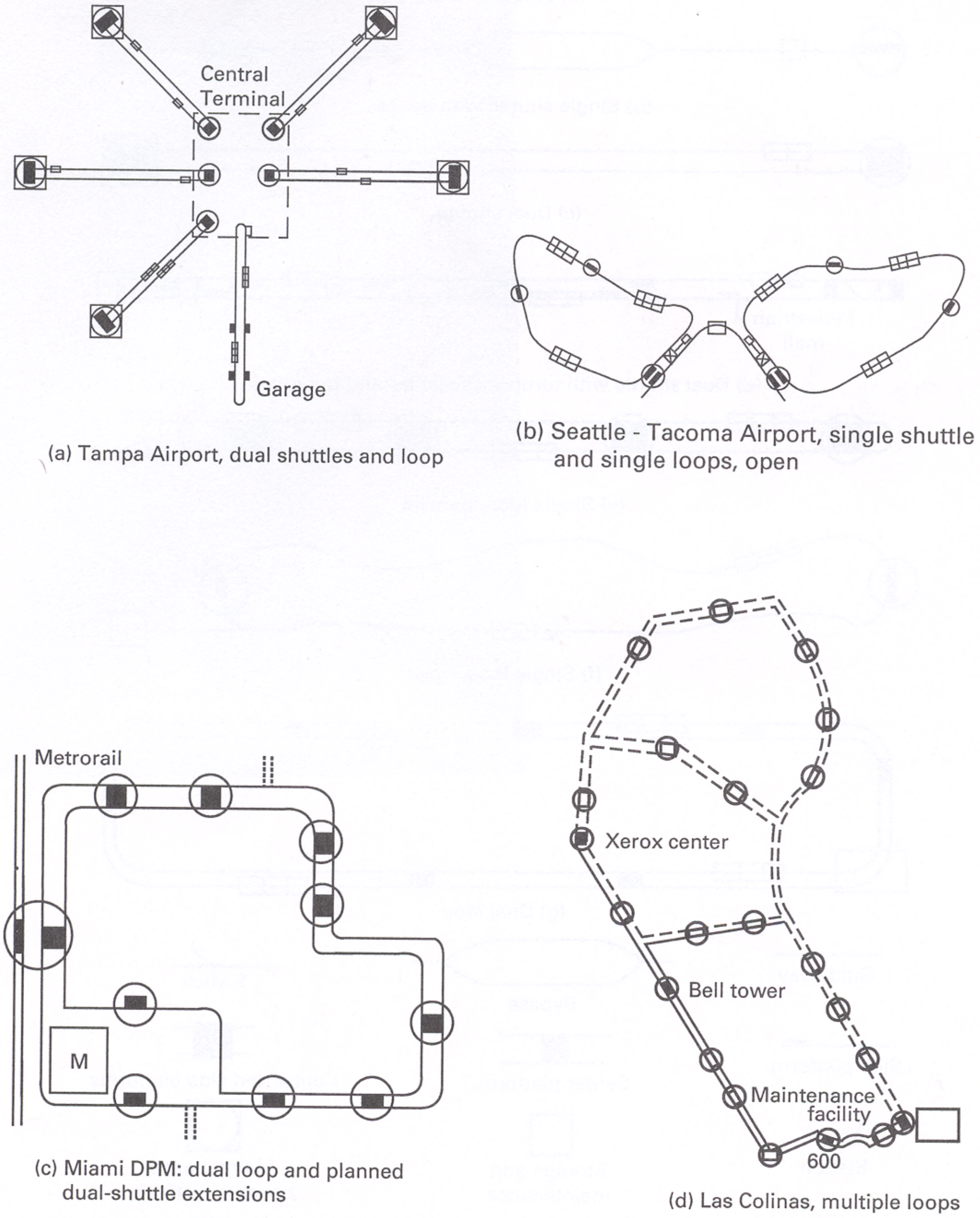


Figure 24-1 *Diagrams of shuttle and loop systems.*



(a) Tampa Airport, dual shuttles and loop

(b) Seattle - Tacoma Airport, single shuttle and single loops, open

(c) Miami DPM: dual loop and planned dual-shuttle extensions

(d) Las Colinas, multiple loops

Figure 24-2 *SLT networks.* (See legend on Fig. 24-1.)

and provide useful service when one loop is shut down. Loop guideways and dual-shuttle guideways with turn-back switches can carry three or more vehicles or trains up to line capacity and can provide high capacity and frequent service on long routes.

The average time passengers must wait to board a vehicle will usually be one-half of the interval between departures. (Average waits of more than 35 s for elevator service are considered objectionable in office buildings, hotels, and the like, and may be regarded as a goal for AGT services.)12 Consequently, single shuttles are attractive only for relatively short links.

Effect speed depends on the average waiting time as well as travel time. If a shuttle makes one round trip every 3 min, average waiting time is 90 s. If average speed is 10 mi/h (16 km/h), travel time for a 1000-ft trip (305 m) is about 68 s. Total trip time is 158 s and effective speed is 4.3 mi/h. Waiting time can be reduced 50% by employing a bypass and two vehicles. The effective speed would then be 6.0 mi/h. These effective speeds are greater than normal walking speed and would be attractive in many circumstances. Higher effective speeds are usually desirable, however, and are readily attainable.

Examples of SLT Systems

Single SLT systems can serve small areas, but networks made of independent, interfacing modules and transfer stations will be needed to serve large areas or entire cities. By 1990, about a dozen SLT systems provided urban public transportation service (not counting installations in special settings such as airports, recreation parks, shopping centers, and medical facilities). Networks were beginning to be used, and experience had clearly demonstrated the technical feasibility, safety, and reliability of SLT systems, and their suitability for use in networks was not in doubt. Examples of systems and technologies illustrate significant points.

Pearlridge

One of the earliest and simplest single-shuttle systems began operations in 1977 at a shopping complex at Pearlridge, Honolulu, Hawaii (Fig. 24-3). The original supplier, Rohr Industries, is no longer active in the AGT business, but Westinghouse Electric Corporation has acquired the product and replaced the original train with a four-car train of updated design called the C-10. Similar systems have been supplied by Transportation Group, Inc., successor to Universal Mobility, Inc., and by Von Roll Transport Systems, Inc.

SLT systems of this general type are relatively inexpensive and are widely used in recreation parks. Guideways are often fabricated steel beams having small cross sections (for example, 30 in x 30 in or 76 cm x 76 cm) Running surfaces for main vehicle wheels are on top and for guide are wheels on the sides. Secondary suspensions are not provided and are not needed for speeds less than about 15 mi/h (24 km/h). Propulsion is by electric motors. Vehicles are bidirectional.

The Pearlridge shuttle includes a single four-car train, two terminal stations, an elevated guideway about 1000 ft long, and a guideway extension for vehicle storage and maintenance. There are no switches. Each train carries up to 48 passengers, 24 seated and 24 standing. Speed is about 10 mi/h. The trains make about 15 round trips per hour. Average waiting time is about 2 min; theoretical capacity is about 720 p/h/d.

This pioneer installation demonstrated that a simple SLT system can provide capacity equal to that of a high-capacity urban bus route (that is, a route using 40-ft vehicles on 5-min schedule intervals or 12 buses/h).

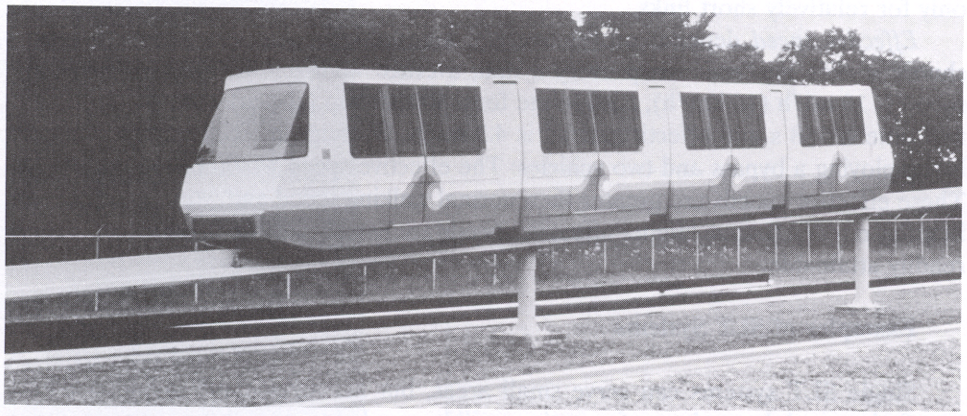


Figure 24-3 *Rohr Monotrain. (courtesy of LEA TRANSIT COMPENDIUM)*

Tampa Airport

The earliest application of SLT systems to form a network was made at the Tampa, Florida, airport in 1971 by Westinghouse Electric Corporation. It embodied innovations of great value for urban applications. The network was formed by independent shuttles that interface at a transfer station. Passengers transfer on foot from one route to another at the interface, but vehicles cannot move from one route to another. Such networks are said to be *uncoupled* (Fig. 24-2a).

The terminal complex originally included a single multistory "land-side" central terminal with highway access and parking and four "air-side" satellite terminals. A fifth satellite terminal and a separate parking garage were added in 1987 and 1991. The land-side terminal (the common station) and each air-side terminal are linked by a dual elevated shuttle (about 1000 ft long), which also includes a median pedestrian walkway for emergency use. In 1990 the shuttle system included almost 1 mi of dual-shuttle guideway and 12 vehicles. The land-side terminal and parking garage are linked by a pinched loop system, using technology similar to Pearlridge, supplied by The Transportation Group, Inc. (TGI), a subsidiary of Bombardier Corp. All originating and terminating air passengers ride one shuttle; some also ride the loop to or from the garage. Passengers changing planes at Tampa usually use two shuttles.

Plans allow for future construction of a sixth air-side terminal, additional parking garages, and a complete duplicate terminal complex. All future facilities will be served by an enlarged SLT network which, ultimately, may include as many as 15 shuttles and loops.

A major objective of the designers of the terminal was to limit total walking distance to about 700 ft or about 2.7 min between ground transportation and aircraft doors. Specifications for the airport called for each route to have a capacity of 840 passengers/10 min/direction to meet surge demands when large planes unload, or about 5000 p/h/d. Vehicles designed to meet these specifications carry up to 100 standing passengers normally. The vehicles have no seats. The vehicle used in the most recent expansion is the C-100. Vehicles accelerate or decelerate during almost all of each trip. Maximum speed is about 35 mi/h (56 km/h). Each vehicle makes 25 round trips/h and has a capacity of up to 2500 p/h/d with normal loading, and two shuttles have a total theoretical capacity of 5000 p/h/d. The fifth shuttle route employs two-vehicle trains and has a theoretical capacity of 10,000 p/h/d. The average time needed for a passenger to make a 1000-ft trip is 75 s, an effective speed of about 9 mi/h.

Shuttle vehicles are maintained in shops located below the guideways and station platforms. There are no switches. A central control facility is located in the communication center of the air terminal and is monitored, as an extra duty, by communication workers rather than by full-time control staff. Vehicle movements are scheduled during most of the day, but service can be provided on demand (in response to a push button) during slack periods.

The airport terminal and shuttle network are an outstanding success. The Tampa airport network carried about 200 million passengers during the first two decades of operation. It is highly reliable and provides service on each route almost constantly, 99.9% of the time. The stoppage of one vehicle does not impede the vehicle on the parallel path, and passengers can usually board the second vehicle with less than a 2-min delay. In the rare case when both vehicles on a route are out of service, travelers may simply leave the platform or the stopped car, which is always possible, and finish the trip on the walkway. The walk requires less than 4 min.

Seattle—Tacoma Airport

The Seattle-Tacoma (Sea-Tac) airport network began service in mid-1973. It employs equipment similar to that of the Tampa network and has also achieved a high degree of success. The network has three underground routes: one single shuttle about 1000 ft long and two single loops about 4000 ft long (Fig. 24-2b). Passengers are always able to utilize a walkway to evacuate stalled vehicles and walk to emergency exits. The shuttle contains two stations. Each of the two loops shares a platform with the shuttle. Passengers transfer on foot at the interfacing stations. The system employs 24 vehicles and has capacities of about 14,400 p/h/d on each loop and 1800 p/h/d on the shuttle.

Centralized maintenance and storage facilities are located between the shuttle and the loops. Transfer tables, rather than switches, are used to move out-of-service vehicles between guideways. Transfer tables are sections of guideway that can be moved laterally from one guideway to another while carrying a vehicle. They are slow but simple, relatively inexpensive, and require less space than switches.

Duke University

A system installed at Duke University Medical Center, Durham, North Carolina, by Otis Elevator Co. began service in 1980. Dual guideways, about 1200 ft long, link two large medical facilities and then merge in a single guideway extension, about 560 ft long, to a parking garage. Vehicles carry 4 passengers seated and 18 standing and also carry cargo. Air cushions, rather than wheels, provide vehicle suspension. Linear induction motors (LIMs), rather than conventional rotary motors, provide propulsion and service brakes. The use of LIMs and air cushions greatly simplifies the mechanical design of the vehicle. Vehicles are guided by pneumatic tires and guide surfaces (curbs) at the sides of the guideway.

Air cushions make it possible to move vehicles laterally, a capability that may be exploited in three ways. At stations, vehicles may be moved between the main guideway and an off-line passenger loading and unloading dock. At the end of the dual shuttle guideway, vehicles may be transferred between guideways for return trips. At cargo facilities, vehicles may be moved between the main guideway and an elevator, which operates to a loading and unloading position on another floor of the building. These capabilities could be used in urban applications to replace elevated station platforms with smaller, simpler, and less costly facilities at sidewalk level.

Harbor Island

A single shuttle with bypass, installed at Harbor Island, Tampa, Florida, by Otis Elevator Co. in 1985, links a retail complex in a multipurpose land development on an island and a multistory parking garage at the edge of the central business district (CBD) of the city (Fig. 24-lb). The system was installed and is operated by a private development company; however, ownership will pass to a public transit authority after 15 years. A fare is charged.

The route is elevated and is about 2200 ft long. A bypass at the midpoint of the line allows two shuttle vehicles or trains to share a single guideway on about 90% of the route and, thereby, avoids a large fraction of the guideway construction costs that would be needed for a dual-shuttle system having the same capacity.

Each vehicle is propelled by a cable and a direct-current drive machine similar to those used in elevators. Vehicles have air cushion suspension and are guided by pneumatic tires and steel curbs at the sides of the guideway.

The vehicles cruise at 25 mi/h (40 km/h). Normal capacity is 100 standing passengers. Two vehicles make about 30 round trips per hjour; theoretical capacity is 3000 p/h/d. Waiting and riding times average about 2.5 min per trip or an effective speed of 10 mi/h.

Shuttle/bypass systems that employ cable propulsion and steel wheels have long been available. A system with rubber-wheel suspension is supplied by VSL Corp. It is not known how the use of wheels rather than air cushions affects capital and operating cost, reliability, safety, and other characteristics, although it does not seem disadvantageous if lateral movement of vehicles is not required.

Atlanta Airport

A dual-shuttle system with turn-back switches and bypasses installed at Hartsfield Atlanta International Airport by Westinghouse Electric Corporation began operations in 1980 (see Fig. 24-ld). The system was designed as an integral and essential part of a new terminal complex, approximately 1 mi long and 0.5 mi wide. It serves a land-side terminal and four air-side terminals, with provisions for future extensions to additional air-side terminals. The system occupies a tunnel some 50 ft underground. A pedestrian mall is located between the guideways. The mall and guideways are separated by walls and access to vehicles is through elevator-type doors. Emergency walkways and exits beside the guideways allow evacuation to the mall in an emergency.

Multiple turn-back switches are employed at each end of the line to provide redundant paths and, thereby, to ensure continuity of service in the event of a major switch failure. Bypasses are provided at the midpoints of each shuttle to ensure continuity of service, at reduced capacity and frequency, in the event of a major failure on the other guideway and to allow shutdown of a guideway for maintenance during slack periods.

The C-100 vehicle is used in trains of up to four vehicles. Trains operate on 100-s headways (36 trains/h) and theoretical capacity is 14,400 p/h/d. Vehicles are guided by an I-beam mounted between the two running surfaces and 8 guide wheels (in sets of 4) attached to the vehicle bogies, which would retain the vehicle on the guideway in an accident. This is the first Westinghouse Electric system to use switches in passenger- carrying operations. The switches are complex and costly to install and maintain. It is not clear whether the safety advantage of the retention feature warrants the penalties associated with the guidance and switch subsystems.

Houston Airport

The Houston Intercontinental Airport employs an underground loop guideway between three terminal buildings, a hotel, and a parking area. Three advanced systems have been employed for this service. The first used battery-powered vehicles in trains. The guidance system employed a signal wire buried in the pathway, sensors on the vehicle to generate a steering signal, and power steering. The vehicles and controls were adapted from systems widely used in factories and warehouses. The passenger vehicles, however, were designed to operate at speeds about 6 or 8 times as fast as industrial models. The system proved unsatisfactory, possibly because of insufficient technical development rather than fundamental flaws, and was replaced. Wire-following guidance technology, however, is of considerable interest both for AGT and AMTV systems. The second system used vehicles and controls similar to those employed at Pearlridge. It also was judged to be unsatisfactory and was replaced.

The third and current system, in service since 1981, was developed and supplied by WED Transportation Systems, Inc., a subsidiary of Walt Disney Productions, and is highly innovative. The product has since been acquired by TGI. Vehicles are passive; propulsion and service braking are by LIMs. Reaction plates are mounted on the underside of the vehicles and motor windings, also called stators, are mounted in the guideway at about 10-ft intervals. Sensors in the guideway and central control apparatus determine the locations, speeds, and separations of vehicles. The central controls adjust the power levels of individual stators to ensure that each vehicle maintains proper speeds and separations. Vehicles employ small-diameter solid tires and have no secondary suspension. Guideways are steel rails fabricated of welded steel tube.

The costs of the vehicles and tracks are relatively low, but the advantages tend to be offset by the relatively high costs of stators and sophisticated controls. These cost characteristics are most attractive when many vehicles operate at short headways on heavily traveled routes rather than on low-volume routes.

The system has attractive maintenance characteristics. The cost of maintaining vehicles and guideways is low. The failure of one or a few stators does not stop operations, and failed units are easily replaced during overnight maintenance periods.

The route includes ten station stops—five stations, each serving two-way traffic. The route is 3680 ft (1121 m) long and will be extended to serve future terminal expansions. A maintenance facility at one end of the loop is connected to the passenger route by switches. The system uses 3-car trains, each with a design capacity of 36 passengers, 18 seated and 18 standing. Maximum speed is 15 mi/h. Theoretical capacity is 1440 p/h/d at 90-s headway.

Vancouver

The Vancouver, British Columbia, SkyTrain system, in service since 1986, was installed by UTDC, Inc., a member of the Lavalin Group. The system is also called Advanced Light Rapid Transit (ALRT). This is the first line-haul AGT system in North America, that is, a system large enough to make a major contribution to the urban transportation needs of a city. The length of the initial route, plus an extension, is 15.2 mi (24.5 km). About 75% of the route is on an elevated structure, 3% is on a purpose-built bridge, 15% is at grade, and 7% is underground in a former railway tunnel beneath the CBD. It employs a dual shuttle guideway with turn-back switches. The route, previously served by buses, is a radial line extending from the CBD to an outlying suburb. The system employs 114 vehicles in married pairs and can operate 2-, 4-, or 6-vehicle trains. Vehicles carry 40 seated passengers and up to 112 passengers (at 8 passengers/m2). Peak-hour capacity is said to be 25,000 p/h/d.

The system includes three significant innovations. First, guidance and suspension are provided by standard-gauge steel rails and flanged steel wheels with steerable trucks, which allow shorter-radius turns than standard trucks without severe friction and noise. Second, vehicle propulsion and service braking are provided by LIMs, with stators mounted on the vehicles and reaction plates mounted between the guideway rails. Third, the automatic control system employs moving blocks, rather than fixed blocks. Claimed advantages are that the use of LIMs eliminates dependence on the low and unpredictable friction between steel wheels and steel rails for acceleration and primary braking and is an improvement over rubber tires on snow and ice, that the combination of LIM propulsion and unpowered wheels provides significant cost savings, and that moving blocks can provide relatively short headways with safety.

Detroit DPM

The Detroit Downtown People Mover (DPM) was installed by UTDC Corp. and began service in 1987. It is one of three UMTA-sponsored DPM systems constructed for urban public transportation service and organized as an integral part of the local transit agency. It uses technology similar to the system in Vancouver. The route is an elevated, single-guideway, open loop 2.9 mi (4.7 km) long and includes 13 stations.

Miami DPM

The Miami DPM (see Fig. 24-4) was the first of the UMTA-sponsored DPMs. It was installed by Westinghouse Electric Corporation and began service in 1986. The C-100 vehicle is employed. Phase 1 is an elevated double-loop guideway 1.9 mi (3.0 km) long located within the CBD and in adjacent land where the CBD is likely to expand. By 1994, phase 2 will provide two extensions of dual guideways to high-density, multiple-use areas at a cost of about $100 million/mi. Total length will then be 4.4 mi. The counterclockwise loop of the original system will be connected to the extensions. Several operating patterns are possible (see Fig. 24-2c).

The Miami DPM and heavy rail system were planned to complement one another and provide an example of a network using both conventional and advanced transit modes (see Chap. 5).

Las Colinas

The Las Colinas Urban Center is a 12,000-acre private real estate development near Dallas, Texas. An SLT network will be installed and operated by the developer and with private funds. Plans call for the eventual construction of 6 mi (9 km) of dual guideway in a network of 4 loops to serve the 130-acre core area. One long loop will operate counterclockwise around the periphery of the core area and 3 short loops will operate within the core area, as shown in Fig. 24-2d.

The initial phase started service in 1989 and includes two shuttle routes and 3 mi of guideway. It was installed by Westinghouse Electric Corporation and employs, for the first time, a 45-passenger (C-45) vehicle. The vehicle is similar to the C-100 model, except for size. A new switch is employed to invert a section of guideway, along a longitudinal axis, to present tangent, turnout, or wye paths.

Japan

Several urban SLT installations have been made in Japan. The first of these are systems at Kobe by Kawasaki and at Osaka by Niigata, which began service in 1981. Both systems serve new towns on artificial islands and provide links from the island to the public transportation systems of the city. The system at Osaka is notable because

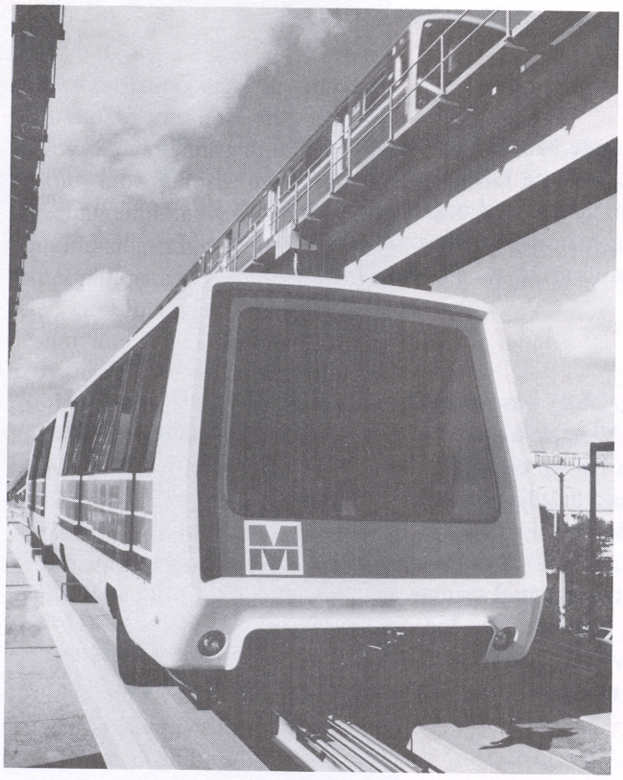


Figure 24-4 *Miami Metromover (courtesy of AEG Westinghouse Transportation Systems, Inc.)*

the new town includes an attractive residential area with high-rise buildings and abundant open space from which automobiles are excluded. Owners of the systems expect to pay both operating and capital costs from fare revenue.

France

A line-haul system at Lille, France, by MATRA, began service in 1983. It was initially planned on a relatively modest scale as an elevated dual-guideway shuttle to link a new-town complex with the central city. The system gained broad community and government support and was greatly enlarged. It has 40 mi (64 km) of dual guideway and 45 stations in two main transit routes crossing the entire city.

A large fraction of the route is underground. The system employs unusually narrow cars to reduce the construction costs of underground facilities. The low capacity associated with narrow cars is offset by short headway intervals gained by the use of automatic controls. Thus, advances in control technology were exploited to reduce construction costs.

The vehicle is steered by guide wheels bearing against curb rails beside the guideway. The rails also serve as power conductors. Switching at branch and merge points employs a double-flanged steel wheel mounted on the center line of each truck and a guideway-mounted switch derived from railroad technology. This is a fast operating, mechanically simple switch and requires no extra space.

MATRA systems of this type have been installed in the United States at the Chicago O'Hare airport and in downtown Jacksonville, Florida, and in other cities in France.

Urban Networks

SLT networks could be developed to serve densely developed major activity centers, such as the central business districts of large cities and multipurpose real estate developments. For example, a grid using 40 shuttle links of 1000-ft length could serve an area as large as the Chicago Loop district [about 1 mi2 (2.6 km2)]. Trips of three or four links might be typical. Passengers would transfer between vehicles at every node, and effective speed would be about 6.8 mi/h. Travel time for such a trip would be about 6 min. Maximum walks between stations and points in the area would be about 500 ft or less than 2 min.

Installing a fine-mesh network throughout an existing CBD may be impossible because of the difficulties in obtaining rights-of-way and the high costs of construction. On the other hand, installations made in a newly developing suburban activity center during construction would entail relatively low costs and few difficulties and would permit greater densities than are now observed.

It is technically feasible to design fine-mesh SLT networks to serve entire cities. However, it will be difficult to obtain rights-of-way and to finance construction. These difficulties are discussed at greater length under PRT.

GROUP RAPID TRANSIT

GRT systems are characterized by the use of switches or other means of steering to allow vehicles to follow branching and merging paths for two purposes. First, GRT station platforms are off-line (that is, located on sidings off the main guideway) to allow vehicles stopping at the station to stand clear of the main line while other vehicles pass without stopping. Second, GRT systems employ multiple, partly overlapping loops, with each vehicle programmed to follow a particular loop and to stop at certain stations and bypass all others. Passengers must board the correct GRT vehicle to reach a specific destination and will often have to wait while other vehicles stop or pass the station.

GRT systems represent a level of technical sophistication and may provide a quality of service intermediate between SLT and PRT systems. In a full-service transit program, multiple GRT elements and transfer facilities could be used to form networks serving large urban areas. The main advantages of GRT, versus an SLT network, are that GRT riders would need to make fewer en route station stops and fewer transfers. These advantages are offset, to some extent, by the need for extra waiting time to board vehicles and, in some cases, more circuitous routings. Comparisons of the services and costs of GRT versus SLT networks would have to be made for each application.

GRT systems were installed during the early 1970s at West Virginia University, Morgantown, West Virginia, and at the Dallas—Ft. Worth Regional Airport. Both systems represented major technical advances over existing SLT systems. Both were undertaken without adequate preliminary analysis and on tight schedules. Both experienced severe and costly development problems and delays in starting service. In retrospect, it can be argued, in both cases, that an SLT network could have provided superior passenger service for most travelers and could have been developed, installed, and operated with lower risk and at lower cost. No additional GRT installations had been made by 1990.

Morgantown

The Morgantown GRT system was jointly planned by the university and UMTA as a research, development, and demonstration project with the intention that it would continue in revenue service. The system started service in 1975, after major delays for reorganization and redesign. It was installed by a team headed by Boeing Aerospace Company. The system includes 3.3 mi (5.3 km) of double guideway, two terminals and three intermediate stations, 45 cars, and a maintenance and operations center. The intermediate stations have off-line guideway paths and platform positions that allow vehicles to bypass without stopping, to stop and then continue in the same direction, or to stop and turn back in the opposite direction. The turn-back feature can reduce capacity on routes having low demand and thereby increase vehicle productivity and lower operating costs and energy consumption. The stations, however, are costly to construct and occupy a considerable amount of space, which would often be difficult to obtain and costly in an urban application.

The conceptual roots of the system was a dual-mode PRT system called StaRRcar that would have employed automotive-type running gear and steering. The Morgantown system employs similar technology. Articulated mechanical arms and wheels on each side of the vehicle follow either the right or left curb on command. The movements of the arm generate steering signals, and a power steering subsystem guides the vehicle. This method allows short-radius turns and, like the wire-following guidance previously discussed, eliminates the need for mechanical switches in the guideway. Eliminating mechanical switches would allow significant cost savings in a major urban network, since switches would be needed in vast numbers.

The Morgantown system can operate in both scheduled and demand-responsive modes. Vehicles operate only as single units, are unidirectional, and can carry up to 21 passengers, 8 seated and 13 standing (see Fig. 24-5). The maximum vehicle speed is 30 mi/h (48 km/h). Average speed is about 19 mi/h. Waiting time varies from 2 min at peak periods to 5 min in slack periods; the minimum headway is 15 s. The maximum theoretical capacity is about 5000 p/h/d. In practice, the capacity is about 3500 p/h/d. The system operates well and provides a valuable service.

Boeing has withdrawn from the AGT business, and some purpose-built technical hardware is no longer available from original suppliers. The lack of continuing support from suppliers has been burdensome and costly to the owner.

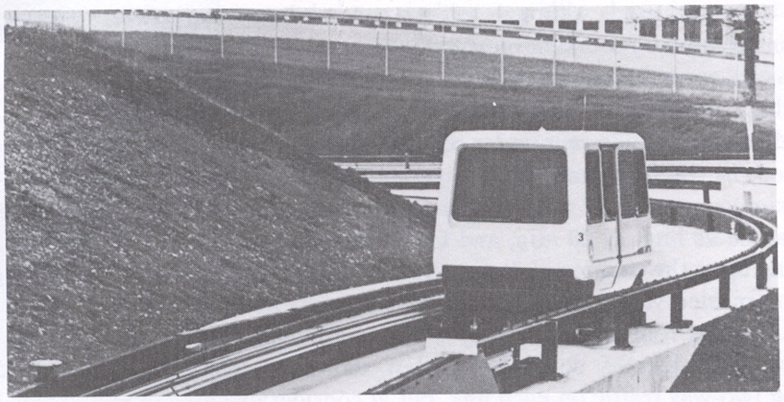


Figure 24-5 *Morgantown vehicle. (courtesy of Boeing Aerospace Company)*

Dallas–Ft. Worth Regional Airport

The Airtrans GRT system at the Dallas–Ft. Worth Regional Airport was installed by Vought Aeronautics and has been in service since January 1974. The system is far more complex and versatile than any other AGT system constructed through the 1980s (see Fig. 24-6). Originally, it contained the following major elements:

- 13 mi (21 km) of one-way guideway.
- 55 station stops: 14 for passengers and visitors, 14 for airline employees, and 27 for mail, baggage, supplies, and solid waste.
- 68 vehicles: 51 for passengers and 17 for material.
- 74 switches.

Routes were designed to allow vehicles to operate in a scheduled mode over 17 distinctly different service loops as follows:

- Five loops for passengers and visitors, including two between remote parking and terminals and three among terminals.
- Two loops for airline employees between remote parking lots and terminals.
- Two loops for mail between terminals and the air mail facility.
- Four loops for interline baggage and mail transfer.
- Four loops for solid waste and supplies.

The baggage service was abandoned because it was not fast enough to make interline transfers of baggage while passengers changed planes. The mail and solid waste multiple independent GRT elements. Also, SLT and GRT modules could be combined in a network.

PERSONAL RAPID TRANSIT (PRT)

Personal transportation systems serve individuals traveling alone or small groups traveling together by choice in small-capacity vehicles routed directly from origin to destination. Conventional personal transportation systems include private automobiles, taxis, bicycles, motorcycles, and wheelchairs. PRT systems are distinguished by the use of automated vehicles and exclusive guideways to provide prompt, nonstop, transfer-free personal transportation service among all the stations of a network, which might be large enough to serve an entire city or metropolitan area. Automated control of empty vehicle redistribution and storage and of vehicle movements in maintenance and service facilities would facilitate intensive utilization of vehicles and lower capital and operation costs.

The term PRT was first used in 1968 in *Tomorrow's Transportation*[13] and is well suited as the name for AGT systems that would have many of the comfort, convenience, and performance characteristics of private automobiles and taxis. Many conceptual designs have been described. Among these are a design prepared and published by Fichter in 1964. It would use a one-passenger vehicle. Vehicles would operate in short trains to accommodate small travel parties. Maximum speed would be 30 mi/h. Size would be about 32 in wide, 78 in long, and 64 in high (81 cm x 198 cm x 163 cm), with a guideway about 36 in wide and 18 in deep. The characteristics of that system are now called PRT.[14]

Stanford Research Institute described a PRT system concept in 1968[15] (together with several other conceptual designs for advanced systems). Haikalis described a PRT system called Supra-Car in which vehicles and guideway columns would be equipped to lower vehicles to platforms at ground level.[16] Avery described a PRT system based on cable propulsion.[17] Several test vehicles have been developed by others. The Romag system (Rohr Industries, U.S.) used vehicles suspended below the guideway and a sophisticated electromagnetic subsystem for suspension, propulsion, braking, and guidance, thereby achieving a much simpler mechanical design than that of other AGT systems. Aramis (MATRA, France) used an optical subsystem that allowed groups of vehicles to operate with 30-in (0.75-m) spacings. Cabintaxi (MBB, Germany) used a guideway with supported vehicles on the upper surface and suspended vehicles attached below the guideway.

CVS

A PRT prototype system called the Computer Controlled Vehicle System (CVS) was developed in Japan in a program started in 1968.[18] The CVS program was sponsored by the Ministry of International Trade and Industry and had numerous participants, including Tokyo University and eight industrial firms. A 2.9-mi (4.7-km) network of guideways was constructed near Tokyo, and 84 passenger and cargo vehicles were fabricated. Passenger vehicles carried four seated passengers and no standees. Cargo vehicles carried payloads of 660 to 880 lb (300 to 400 kg). Speeds ranged from 24 to 48 mi/h (39 to 77 km/h). The goal was to achieve theoretical capacities of 3600 vehicles/h. Headways of 1 s were achieved in tests with three vehicles at speeds up to 18 mi/h. The CVS test program was the largest and most extensive that has been conducted for PRT systems. The project was abandoned, however, and the extensive test facility was dismantled.

TAXI 2000

In 1989 a technical committee of the Advanced Transit Association (ATRA) found only one active PRT development program.19 The program was conducted by the TAXI 2000 Corporation, but has a 20-year history under the leadership of Dr. J. Edward Anderson, former Professor of Mechanical Engineering, University of Minnesota. The program is privately funded and proprietary.

The TAXI 2000 vehicle design is illustrated in the ATRA report. The guideway cross section is 36 in (0.9 m) square. It is made of prefabricated steel girders and has a slot in the top surface. The vehicle bogie is enclosed within the guideway and includes a total of 16 wheels for suspension, guidance, and switching. The bogie also carries dual solid-state power conditioning equipment and a pair of LIM stators. The body is entirely above the guideway and is structurally connected to the bogie through a narrow slot in the top of the guideway. This arrangement would exclude snow and ice, which has been a major problem at Morgantown and Dallas—Ft. Worth, where guideways are unsheltered. It would also help to minimize the bulk and visual impact of the vehicles. It appears, however, that the design would complicate the maintenance of the guideway and repair of vehicles that fail while on the guideway.

Dependable estimates of the costs of a TAXI 2000 system (or any other advanced system) cannot be made until detailed technical data are available on the equipment and facilities to be used for a particular system and installation. Sales literature indicates that the system will cost $10 million/lane-mi, but detailed data were not provided.

Vehicle Capacities

Conceptual PRT vehicles vary in passenger capacity, and the optimum size has not been determined. The average number of passengers per loaded vehicle would likely be in a range of 1.2 to 1.5 persons, depending on the purpose of the trip, as in automobiles. Fichter proposed a 1-passenger vehicle. A vehicle of the same width but longer could carry 2 passengers. Stanford Research Institute proposed a 4-passenger vehicle with 2-abreast seating.20 The TAXI 2000 vehicle is 5 ft 4 in (1.63 m) wide and 4 ft 6 in (1.37 m) high and would carry 3 passengers on a single, forward-facing seat. It should be noted that the choice of vehicle width and passenger capacity will affect the size, visual impact, and cost of elevated structures and the size and capital cost of the vehicle fleet.

Link Capacities

PRT system concepts call for vehicles to follow one another with short time intervals or headways. Experience with automobiles on typical freeway lanes can be used to place this characteristic in perspective. Freeway lanes can carry up to about 1800 automobiles/h under peak load conditions; the average headway is 2 s. At 40 mi/h (53 km/h), the average headway distance is about 117 ft (37 m), and the actual clearance between automobiles is about 100 ft. With average loads of 1.33 persons per automobile, such freeway lanes carry up to 2400 travelers/h. Some PRT conceptual designs call for average headways much lower than 2 s and lane capacities higher than those observed for automobiles in highway lanes.

Short headways have not been achieved on guideway systems in revenue service. Existing rail rapid transit systems seldom operate with headways below 100 s. The two GRT systems were designed to achieve minimum headways of only 15 to 18 s; however, average headways are significantly longer in practice. A major research and development effort would be needed to achieve minimum headways of 2 s or less with safety, reliability, comfort, and acceptable cost if, indeed, such headways are attainable. Only a limited amount of work has been done on these problems, and much of that may have been lost when various program and research projects were terminated.

Important questions remain to be resolved about the headways actually needed in PRT systems. The headways required would vary greatly among links of a PRT network and, on most links, will be much longer than 2 s. Traffic on those routes that appear to require large capacities can be accommodated without extremely short headways by (1) dividing the loads among links of a finer-mesh grid or (2) employing rail transit or larger-capacity AGT systems, rather than PRT, on heavily traveled routes.

Stations

The complexity of PRT stations would vary with the capacity required. Some PRT stations may need the capacity to unload or load up to 1000 vehicles/h, or at average rates of 1 vehicle/3.6 s. The standing time required to unload or load a PRT vehicle is likely to be 10 s or longer. Therefore, a simple siding would not have sufficient capacity. Several ways to increase capacity have been suggested. Among these are parallel platforms, dynamic platforms, and transfer tables and elevators. On-line stations can be used on low-volume links.

Urban PRT Networks

A single, fully coupled PRT network could serve all or a large part of a city or metropolitan area. Lines could be arranged in a gridlike pattern along city streets or in any other pattern to suit particular sites.

Several PRT conceptual designs have proposed fine-mesh networks with spacings of 0.25 mi (0.4 km) between parallel lines and 0.25 mi between stations, which would be most effective if located about midway between nodes (interchanges). In such networks, maximum walking distances for access to stations would be about 0.125 mi or 660 ft (201 m) and would require about 2.5 min at normal walking speed. Most travelers would find these walking distances tolerable or even attractive except in inclement weather and in areas where personal security is of concern. On the other hand, travelers who are physically handicapped or encumbered with small children, groceries, parcels, or luggage would consider the walks burdensome or impossible. Very fine mesh PRT networks are not likely to be economically feasible because the cost of a PRT system would increase as the spacings between lines and stations decrease. It is important to note that the need to walk to and from stations is an important limitation on the usefulness of all fixed-route transit systems. Means to supplement PRT service are discussed under PAS, D-AGT, and AMTV.

The use of 0.5 mi spacings, rather than 0.25 mi spacings, would reduce capital costs and the difficulties of obtaining rights-of-way, but would double walking distances. Without supplemental services of street transit systems for station access, such spacings would effectively deny service to many travelers.

Some PRT concepts envision networks with two-way guideways, two-way stations, and full twelve-way interchanges at nodes. Others would achieve significant reductions in capital costs and visual impacts by using one-way guideways and stations and four way interchanges (two crossing lanes to accommodate through traffic and two turning lanes). A major disadvantage of one-way networks is that routings of vehicles would be circuitous. An average of four grid intervals (for example, 1 mi in 0.25-mi mesh) would be added to each round trip. The median trip length in many cities is quite short. An average increase of 0.5 mi per one-way trip might be as much as a 20% penalty in travel distance, and would increase operating costs and travel times by significant amounts.

Additional measures that address the need to achieve low capital costs and to minimize the offensive visual impacts of elevated guideways and stations installed in street rights-of-way are:

1. Reduce guideway radii and lengths of guideway structures for left and right turns.
2. Locate stations at grade on space taken from parking strips and sidewalks or on land acquired for the purpose.
3. Use on-line stations on links that have low traffic flows to eliminate off-line guideway structures.
4. Use elevators to transport vehicles between elevated guideways and platforms at ground level to eliminate elevated stations.

San Francisco Example

Although the cost of a PRT network cannot be estimated definitely until detailed designs are prepared, it is likely that a PRT network for a city of moderate physical size would entail multibillion-dollar outlays. To gain some perspective of the problem, a sketch planning exercise was conducted for the city and county of San Francisco. San Francisco has a resident population of about 740,000 in the 1990 census and a total area of nearly 50 mi2. Some areas would not require PRT service, so a service area of 40 mi2 was assumed. It was assumed that one-way guideways would be used in a fine mesh (0.25-mi) grid. Eight miles of guideway and 32 stations would be needed per square mile or a total of 320 mi of guideway and 1280 stations. It was assumed that the capital cost of the entire system would average $10 million/mi. The total capital cost would be $3.2 billion and the average capital cost per resident would be about $4300. Financing a project of this magnitude would establish a new record for the city, but might be acceptable to voters, since it could increase individual mobility, reduce existing congestion, and reduce air pollution.

San Francisco provides more fertile ground for advanced systems than most other U.S. cities. It has high demand density because the population density is high, the fraction of households without automobiles is also high (about one-third), and there are no low-density fringe suburbs. The capital cost of PRT systems per resident in most low- density cities would be much greater than in San Francisco. If the costs of PRT in San Francisco were found acceptable, it would not necessarily mean that networks covering large fractions of other U.S. cities would be acceptable.

Major efforts to achieve low costs would make extensive use of PRT more likely. Even so, in areas of low demand density, it will be necessary to consider networks that use widely spaced routes and stations or the elimination of PRT service entirely in areas of low demand density.

Chicago

The Regional Transportation Authority (RTA), Chicago, Illinois, is the first public transit agency in the United States to make a major commitment to the evaluation of PRT. In April 1990, the authority announced the start of a three-phase program to test and evaluate a PRT system in an urban setting. The first phase will include preliminary engineering studies by two contractor teams, in parallel, each with $1.5 million contracts and 1-year schedules. The second phase will involve one team of suppliers. It will include fabrication of equipment, development of software, construction of a test track of sufficient size to evaluate the system, and conduct of tests. The second phase will be jointly funded by RTA and the suppliers. If the test results of phase 2 are satisfactory, phase 3 will be undertaken. The supplier will fabricate, construct, and operate a prototype PRT system in revenue service at a suburban demonstration site. Phase 3 will be funded by RTA. If PRT is not feasible, RTA will continue to seek improvements in transit service with advanced systems of other kinds.

PUBLIC AUTOMOBILE SERVICE (PAS)

PAS systems would supply small automobiles for rent by the trip to accredited drivers. In a full-service transit program, the principal role of PAS would be to provide service between stands located near transit stations and stands located within easy walking distances of actual origins and destinations of trips. PAS would also provide service for relatively short trips where the use of other transit modes would not be practical. PAS would not be a substitute for the automobile, taxi, or transit for trips longer than perhaps 1 to 2 mi.

Several rent-by-the-trip systems employing ordinary automobiles have been developed and demonstrated in limited applications, such as service for residents in a San Francisco apartment complex. The Witkar system was developed and deployed on a limited scale to provide public transportation service in downtown Amsterdam, the Netherlands. It employed simple, lightweight, battery-powered vehicles, curb-side stands, and access-control and fare-collecting subsystems. These systems were underfunded and, therefore, not able to maintain their operations long enough for evaluation of viability. The following discussion is based on a conceptual system called Public Automobile Service (PAS) developed and described in 1968.21

Purpose-built vehicles and equipment would be developed for the specific needs of the service. Vehicles would be battery powered and would be recharged while parked at stands. Speed would be quite low in comparison with automobiles. Maximum speed would be limited to, perhaps, 20 mi/h for fully qualified drivers and 10 mi/h for those with special licenses. Vehicles would be designed for efficient redistribution in trains of empty cars. Purpose-built vehicles have high unit costs when produced in small quantities; however, the cost of lightweight, low-performance PAS vehicles in quantity production could be less than the cost of small conventional automobiles.

Access to PRT vehicles would be limited to licensed and accredited clients. Operating PAS vehicles would present no problems for licensed drivers, and it is likely that many who do not have drivers licenses could be trained to operate PAS vehicles safely on local streets at low speeds and be given special licenses. To satisfy the full-service transit standard, travelers who did not qualify for access to PAS vehicles could be served by dial-a-ride systems or by AMTV systems.

The number of vehicles on hand at each stand would be monitored from a central control facility, and empty vehicles would be redistributed from time to time in anticipation of shifting demands. Movements of empty vehicles could be done in two ways: in trains controlled by a driver or by employing the AMTV techniques discussed later.

PAS vehicles and stands would be vulnerable to vandalism and might become attractive targets, especially to individuals who were denied access to vehicles. This risk is difficult to assess in the absence of experience, but is likely to make it impractical to use PAS vehicles in certain areas.

DUAL-CONTROL AGT SYSTEMS (D-AGT)

In a full-service transit program, dual-controlled AGT systems address the same needs as a combination of an AGT network and a PAS system. D-AGT systems of many kinds can be envisioned. The common characteristics are capabilities to operate vehicles both under automated controls on exclusive guideways and under manual controls on city streets. These concepts are being considered as part of the "smart highway" research. Most D-AGT systems would also require dual-power systems (for example, power from wayside electric conductors while on guideways and from engines, batteries, or fly-wheels while on city streets).22

Dual-mode bus systems have been developed and have had limited use in Europe, Japan, and Australia and appear to promise three main advantages over separate AGT and conventional bus systems. First, drivers are not needed to control the vehicle while traveling on the guideway. Yet, this does not necessarily mean that labor costs would be reduced. Ideally, the driver who delivers a bus from the street to a guideway on-ramp would be assigned immediately to another vehicle leaving an off-ramp for travel via street. In fact, it is likely that such close coordination would not be possible. Probably only a small fraction of the labor could actually be utilized, so the labor cost savings may be small. Second, travelers would not have to transfer on foot between street vehicles and guideway vehicles. This would benefit the traveler, but it may be difficult for the system owner to convert the benefit to revenue to pay extra costs. Third, dual-mode buses may operate on close headways to more effectively utilize heavily traveled traffic lanes on bridges, in tunnels, and in similar lanes that are exceptionally valuable and costly to replicate. The ability of dual-mode buses to operate safely at headways shorter than those achieved by driver-controlled buses has not been demonstrated. Also, the length of such links comprise only a minor fraction of bus route networks.

The apparent advantages and disadvantages of dual-mode AGT systems using vehicles with GRT or PRT passenger capacities are similar, in some respects, to those of dual- mode buses. Travelers would be relieved of transfers. There would be little or no savings of driver costs. Areawide use of D-AGT, as an alternative to an AGT network plus conventional buses and other street vehicles, appears to have numerous disadvantages. Foremost among these are additional cost. The essential characteristic of street and AGT vehicles would have to be combined in heavier, more complex, and more costly D-AGT vehicles. On-and-off ramps would have to be added to guideways. Automated test equipment would have to be developed, produced, installed, and maintained, and each vehicle about to enter a guideway would have to be tested to determine that it is functioning properly. Dual-mode systems must use vehicles with automotive-type suspension, propulsion, braking, and steering. Subsystems such as air cushions, magnetic levitation, LIMs, and suspended vehicles would be excluded even though they may offer major advantages when used in AGT systems.

It is also important to note that while on the streets dual-mode PRT would only be usable by accredited drivers and their traveling companions. Other travelers would continue to walk or depend on other modes.

AUTOMATED-MIXED TRAFFIC VEHICLE SYSTEMS (AMTV)

AMTV systems would employ vehicles using a combination of automated, remote, and passenger-activated controls and nonexclusive guideways shared, in varying degrees, with pedestrians and other vehicles. The objective would be to avoid the cost of paid drivers and the cost of guideways and station structures.

In a full-service transit program, AMTV vehicles would provide service to and from transit stations and for other relatively short trips. AMTV systems could address the same needs as PAS and dial-a-ride and might make those systems unnecessary. AMTV systems would also provide low-cost alternatives to AGT systems on low-volume routes. If AGT systems cannot be widely used because of excessive costs, visual impacts, or other reasons, AMTV systems may be the last best hope for full-service transit.

The technology of very low speed A M TV systems is well established. Many systems are used for materials handling in factories, warehouses, office buildings, and hospitals. These vehicles travel about 1 mi/h and are too slow to have much value for passenger service. Higher speeds are presently considered unsafe. The vehicles rely on sensitive bumpers to disconnect power and apply brakes when the vehicle contacts anything in its path. The time available to stop the vehicle before striking the obstacle depends on the reach of the sensitive bumper and the cruise speed of the vehicle. Techniques are needed to achieve higher speeds with safety. Among these are sensors and other devices to give vehicles greater warning of possible collisions and means to limit random access to the guideways.

Several low-speed AMTV prototypes have been developed for passenger service, but none has reached revenue service.23 In 1974-1976,General Motors Corporation developed and demonstrated an AMTV vehicle operating among pedestrians in a shopping mall at about one-third walking speed. In 1974, Otis Elevator Company developed a similar prototype and conducted tests in an airport terminal. In the mid-1970s, Jet Propulsion Laboratories developed and installed a prototype AMTV system within its laboratory grounds. The vehicle shared rights-of-way with motor vehicles and pedestrians. It employed both an elongated sensitive bumper and a forward-looking optical sensor. The aim was to detect obstacles soon enough to allow safe stops from a speed of about 7mi/h (11 km/h), more than double normal walking speed and sufficient to be highly attractive in urban service. However, the detection subsystems were not adequate under some circumstances, and it was necessary to carry a standby operator aboard the vehicle to take control when the automatic equipment failed. None of these systems reached regular passenger service. One major factor was concern over safety and public liability in A M TV systems designed to operate at speeds high enough to make the service attractive.

Eliminating drivers would avoid high labor costs. Operating vehicles on nonexclusive guideways, mostly at grade, and rarely with elevated guideways and stations would avoid most construction costs. Most rights-of-way for AMTV networks would be obtained at low cost from traffic lanes of existing streets and curb-side parking strips, as is often done for bike paths; by sharing rights-of-way with pedestrians on sidewalks, in parks, and in shopping malls and multipurpose activity centers; and by using other expedient rights-of-way. Some new rights-of-way would have to be acquired for AMTV stations and vehicle storage. Most of the aesthetic offenses of AGT guideways and stations would be avoided. Together, these features would reduce the most serious disadvantages of conventional and other advanced systems in a full-service transit program. Consequently, the incentives to develop safe and effective AMTV systems are very great. There are two main challenges for AMTV designers. For safe operations, AMTV need sensors and braking systems that can reliably detect fixed obstacles or possible intercepts with moving objects and bring vehicles to a full stop in time to avoid a collision.

To be attractive, they probably need to achieve *average* speeds of 6 mi/h or more. Sensitive bumpers may be improved to permit safe operation at speeds of about 2 mi/h. An AMTV system will need the capability to operate at several higher speed levels (say 2, 4, 8, and 16 mi/h) and to change speed according to the degree of protection and assurance that can be provided against intrusions of the guideway by cross traffic. The AMTV guideway can be divided into sections, and each section can have a specified normal cruise speed level determined by the degree of protection normally obtained from measures used to limit access to the guideway and to increase warning times. Among these measures are physical barriers at the sides of guideways, sensors on the vehicles, in the vehicle path, and on the wayside to detect obstacles on or near the path, sensors on the wayside to detect movements of pedestrians and vehicles toward the path, pedestrian lanes to limit crossings to certain guideway sections, markers and warning signs at crossing points, pedestrian stop and go signals, control gates for pedestrians and vehicles at crossings, and coordinated automobile and AMTV traffic signals at street crossings. When a possible collision is detected, a vehicle would stop until the risk of collision ends or reduce speed to 2 mi/h and rely on sensitive bumpers. When obstacles are not sensed, vehicles would travel through the section at the designated cruise speed. A considerable effort will be needed to develop, test, and evaluate such techniques.

The technical problems of developing AMTV systems are challenging, but are probably no more severe than for PRT or other fine-mesh AGT networks. The nontechnical problem to be solved before AMTV systems are operational and acceptable in urban settings are more complex and present greater risks. It will be necessary to take (or share) rights-of-way for AMTV routes and stands from other uses; to devise protective measures to limit, to some degree, freedom of movement by pedestrians and other vehicles; to establish and enforce new traffic rules designed to accommodate and protect AMTVs from collisions with automobiles; to educate the public regarding the operation, services, hazards, and limitations of AMTVs; to develop effective and economical ways to handle private and public liability responsibilities; and to develop systems and procedures for vehicle management. A method of fare collection will have to be conceived and developed, if possible. Otherwise, the possibility of providing AMTV service free will have to be considered.

It will be desirable to introduce AMTV systems in special settings providing favorable conditions, such as university campuses, retirement communities, industrial parks, multipurpose commercial facilities, and resorts, before attempting their use in urban transit service.

ACCELERATING MOVING WAYS (AMW)

Accelerating moving ways transport passengers on foot or in small captive vehicles. In a full-service transit program, AMWs would be used in densely populated activity centers and would encourage the preservation and development of such areas.

Each AMW element has three speed stages: (1) accelerate from a low boarding speed to cruise speed (for example, one-third walking speed to 5 times walking speed), (2) maintain cruise speed, and (3) decelerate to the initial low speed. In a full-service transit program, accelerating moving ways would be used in densely populated activity centers, such as central business districts and airports, and would be especially attractive in major activity centers because they have large capacities but require small amounts of space.

The SK system by Soule, S.A., France, is an example of a vehicle AMW. It employs 12-passenger vehicles (6 seated and 6 standing) on a parallel-loop guideway about 13 ft (4 m) wide. Vehicles are drawn by a continuous cable loop at a cruise speed of 12.4 mi/h (20 km/h). Vehicles do not stop at station platforms, but decelerate to a low speed to allow passengers to unload and load. Peak capacity is said to be 3000 p/h/d, which implies 250 v/h/d and about 14-s headways.

Conventional pedestrian conveyors and handrails operate at a constant speed of about 1.5 mi/h or one-half walking speed. Travelers may walk on the conveyor surface to achieve speeds of 4.5 mi/h, a significant improvement. Conventional conveyors are especially useful to travelers encumbered with luggage, parcels, and small children; however, limited speed and high cost deny them a major role in urban public transportation. AMWs with speeds of, say, 7.5 mi/h (two and a half times walking speed) would give more attractive service.

A prototype AMW system without handrails was developed by Applied Physics Laboratory, Johns Hopkins University. Passengers step from a station platform to a conveyor surface moving at one-third walking speed. The surface elongates as it advances until it reaches a speed several times the boarding speed. Near the end of the conveyor the surface contracts and decelerates to the original low speed, and passengers step off the conveyor to a stationary platform.

Prototype acceleration pedestrian conveyors were also developed in Switzerland by Battelle Memorial Institute and by Pierre Petan of the Paris Public Transit Authority (RATP). Prototype versions of these systems have been fabricated, but no AMW system is on the market or in regular passenger service. Rights-of-way for AMWs can be easily provided in new activity centers, but may be quite difficult to obtain in established ones.

FAST TRANSIT LINK SYSTEMS (FTL)

Fast transit link (FTL) systems would provide service at cruise speeds much greater than those of automobiles, buses, and trains, perhaps in the range of 150 to 300 mi/h (240 to 480 km/h). An example was UMTA's Urban Tracked Air Cushion Vehicle (UTACV) system. The vehicle and a short track were developed to the prototype stage by Rohr Industries in the early 1970s, but a full test track was not constructed. The vehicle used air cushions for suspension and guidance and LIMs for propulsion and normal braking. Top speed would have been about 150 mi/h (240 km/h). It would have operated on a elevated guideway with on-line stations. The prototype vehicle would have carried an operator, but revenue vehicles could have been fully automated. The program ended after the LIM and part of the reaction rail were damaged by accidental overheating. In a more fundamental sense, the program was abandoned as UMTA gave up its role as a sponsor of advanced system developments of all types. A similar system was developed in France, but was not placed in revenue *service. Systems developed in Germany* and Japan for intercity passenger service would exploit magnetic suspension and propulsion systems and are being considered in several applications.

Opportunities to utilize urban FTL systems would only be found in a few areas under certain narrow conditions. Especially long routes are needed (50 to 100 miles). Acceleration and deceleration require considerable travel distances; therefore, long intervals between stations are needed to realize significant time savings from the high cruise speeds. The radii of curves must be great to avoid speed reductions. Large passenger loads are needed to justify the capital costs of rights-of-way, facilities, and equipment. These conditions may be satisfied on a few urban routes, such as links to distant airports, but, in the foreseeable future, the need for FTL routes for urban service is very small. Systems developed for high-speed intercity transit systems could be used in those cases.

CONDITIONS FOR SUCCESSFUL INNOVATIONS

If it is determined, as a matter of public policy, that a proper objective of society is to provide full-service transit, certain basic conditions need to be met. Conventional transit modes will not necessarily be displaced, but complementary sets of advanced systems based on existing and readily attainable technologies will have to be developed and deployed. The development of an advanced system should not be undertaken merely because technology is available. The usefulness of advanced systems will often depend on nontechnical conditions that should either exist or appear attainable before large development and planning efforts are undertaken. These nontechnical requirements can be overlooked or neglected in the early stages of programs, but will have to be faced eventually

Before developing an advanced system there is need for evidence that its use will supply services that satisfy genuine needs, that are not available, that are available but are inadequate in quality or quantity, that require excessive costs, or that entail other penalties such as environmental impacts or the excessive use of critical resources. Analysis of the demands for advanced transit services is needed.

To select the most appropriate sets of systems, it will be necessary to compare conventional systems, allowing for possible future improvements, with possible future advanced systems, and to compare various advanced systems with one another. Evaluations and comparisons of alternative systems require the use of several techniques including but not limited to the following. Engineering economy is a method of identifying and comparing alternatives.24 Life-cycle cost comparisons recognize both capital and operating costs over the life of a system and use equivalence calculations at appropriate interest or discount rates and inflation adjustments to make the amounts of money expended at different future times commensurate (that is, comparable at common dates).25 Value engineering is an aggressive and disciplined method of designing equipment and systems to provide essential services without waste of resources.26,27 Energy economy studies estimate total indirect and direct energy demands over the life-cycle of the system and compare alternatives.28 Cost-benefit analysis evaluates both the benefits and the costs of proposed public works, recognizing the interests of all affected parties.29 Simulation analysis uses computer models to describe, compare, and evaluate the operation of systems.

Capable institutions, both private and public, will be needed to plan and manage programs. Private firms will be needed to conduct research, development, testing, and evaluation projects on prototype advanced systems with private funds if there is a reasonable hope of profit or, otherwise, with funds from public sources. Manufacturing firms with long-term commitments to the business will be needed to fabricate and install equipment and to provide technical support, replacement equipment, and equipment for future expansion. Appropriate agencies will be needed to set standards for facilities, equipment, operations, and safety. Consultants and construction firms will be needed to design and construct facilities. Organizations will be needed to operate and maintain the systems. Existing public institutions will need to add staff and develop competence to deal with advanced systems, and many will need broader charters. Some new public institutions will have to be established. The development of public institutions is a complex process and often requires considerable experimentation and time. Business firms, by way of contrast, are highly adaptable and will respond quickly to new challenges when and if a reasonable chance for profit is perceived.

Financing on the order of hundreds of billions of dollars will be needed for the capital costs of major deployments of advanced systems in all urban areas. Conventional transit depends on public funds for all or major fractions of operating and capital costs. By contract, advanced systems designs and applications should aim to limit the need for public funds per unit of service, first, by low-cost designs and, second, by increasing patronage and revenue, in comparison with conventional modes. Still, the total requirement for capital for a full-service transit program will be very great. Innovative programs, however attractive, should not be undertaken until the approximate magnitude of capital and operating costs can be estimated and until there is reason to believe that needed funds can be obtained.

Rights-of-way will have to be obtained. If rights-of-way for elevated or underground facilities are in the public domain, they might be obtained at no cost, with approval of city governments or by special legislation. If rights-of-way in the public domain cannot be used, private land will have to be purchased or taken by court action—a long, costly process. Some rights-of-way on private land might be obtained with relative ease (for example, abandoned rail lines and within new land development projects). Underground structures are very costly, and their construction often disrupts surface activities for months or years; therefore, use of underground rights-of-way should be severely limited. To make elevated facilities more acceptable, considerable effort and expense will be warranted to minimize aesthetic offenses and noise. The problem will be less acute where guideways can be widely separated from buildings, as in the medians of wide streets, and in newly developed areas where rights-of-way can be reserved. Experience with elevated rail lines and early AGT systems suggests that elevated structures are often strongly opposed by citizens, and, consequently, the challenge of obtaining rights-of-way for hundreds of miles of elevated guideway for large networks will be daunting. The cliff culties and delays of gaining rights-of-way and the costs of construction should be considered carefully in choosing between systems that require guideways and those that depend mainly on street vehicles, such as taxis, dial-a-ride, public automobile service, and automated mixed-traffic vehicles systems.

The adoption of a full-service transit standard represents a major change in public policy. Approvals will be needed from legislative bodies; federal, state, regional and local agencies responsible for regional transportation planning; environmental protection agencies; and safety and security agencies. Complex compromises and agreements will be needed among neighborhoods, municipalities, counties, regional authorities, states, and the federal government. These are time-consuming activities. Change of plans will cause delays and increase costs and should be minimized.

The complex issue of proprietary versus standard designs for advanced systems must be resolved in a way that protects the interests of buyers and suppliers. Buyers of advanced systems will be reluctant and, perhaps, unable under law to purchase a major system, such as a PRT network, from a sole source. Suppliers will be reluctant and, perhaps, unable to finance the development of a nonproprietary system but may be willing and able to develop proprietary systems and then to license the designs to other firms to produce them.

Proposals for major installations of advanced systems will usually require voter approval in an election or approval by elected representatives. The public will not have an easy way to become familiar with advanced systems until examples are prominently displayed. In the meantime, a public information program will be needed in each urban area to describe the proposed systems and services and to explain the benefits and costs.

All these conditions and others, no doubt, will have to be satisfied before proposals for major installations of advanced systems can be completed successfully. The difficulty of satisfying the conditions will vary among system types and settings for applications. In the near future, priority should be given to application settings and systems with features that offer a reasonable chance of ready acceptance and early success.

CONCLUSION

The inability of conventional modes to provide full-service transit throughout urban areas, the need for innovations to achieve that end, and the main avenues for the development of advanced urban public transportation systems are clear if not widely recognized. Progress on advanced system development has been slow and ill-balanced, and many programs may have been prematurely aborted. The problems of planning, developing, producing, installing, and operating advanced systems have proved to be far more complex than expected.

The benefits that appear to be available through the exploitation of advanced systems have not been accepted by many established transit experts, are poorly understood by many of the institutions that would have to install and operate them, and are unknown to most of the potential beneficiaries. Consequently, there is no powerful constituency or political force pressing for the application of advanced systems. In the United States it has seldom been politically feasible for federal, state, regional, and local agencies to exercise leadership or develop aggressive innovative programs.

Potential suppliers of advanced systems demonstrated an enormous capability to develop and produce systems in the early 1970s, but many became discouraged by the lack of market opportunities and, later, government interest. The number of major firms with active programs in advanced systems declined substantially during the mid-1970s, but slowly increased during the 1980s. Although numerous capable suppliers exist, it is unreasonable to expect industry to show strong interest in advanced systems until attractive markets are an early prospect.

Perhaps the most serious need is for competent and innovative planning of advanced systems at the regional and local levels. For this planning to be effective, there must be active cooperation among the national professional organizations and agencies concerned with urban transportation and related environmental, resource, and land-use problems.

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EXERCISES

24-1 What are the limitations on more extensive use of rail and bus transit? What characteristics of advanced systems promise to overcome these limitations?

24-2 What are the advantages promised by AMTV systems? What problems need to be solved to make AMTV systems safe and effective?

24-3 Why will fast transit links have limited roles in urban transportation?

24-4 What are the service characteristics of PRT systems? Why are supplemental street systems required?

24-5 What are the major technical and financial problems in implementing fine-mesh AGT systems in large urban areas?

24-6 What are the major institutional and environmental problems in implementing fine-mesh AGT systems in large urban areas?

24-7 Outline the conditions for successful implementation of a full-service transit system in your area or a nearby urban area.

24-8 As a group project, show how advanced systems could be used to provide full service on your campus and in the surrounding neighborhoods. Consider existing and advanced systems. Identify routes and stations. Describe services.